Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

CANMET

Canada Centre for Mineral and Energy Technology
Centre canadien de la technologie des minéraux et de l'énergie

Mining Research Laboratories
Laboratoires de recherche minière

THE TENSILE STRENGTH OF COLD SPRING QUARRY GRANITE DETERMINED BY USING FOUR DIFFERENT TEST PROCEDURES

B. Gorski

MRL 91-040(TR) Apr. 1991

Canada

92-01191/

THE TENSILE STRENGTH OF COLD SPRING QUARRY GRANITE DETERMINED BY USING FOUR DIFFERENT TEST PROCEDURES

B. Gorski

MRL 91-040(TR) Apr. 1991

This document is an unedited internal report prepared primarily for the information and use of the originating Laboratory and its colleagues. It may not necessarily represent final conclusions or opinions of the Canada Centre for Mineral and Energy Technology (CANMET).

Ce document est un rapport préliminaire préparé et rédigé principalement pour les besoins de documentation interne. Il ne représente pas nécessairement les conclusions définitives de l'opinion du Centre canadien de la technologie des minéraux et de l'énergie (CANMET).

15 pp

MICROMEDIA

THE TENSILE STRENGTH OF COLD SPRING QUARRY GRANITE DETERMINED BY USING FOUR DIFFERENT TEST PROCEDURES

by

B. Gorski*

ABSTRACT

Many devices have been developed over the years for the determination of the tensile strength of rock materials. The devices use both direct and indirect methods in the testing and subsequent determination of rock tensile strength. Of these, the direct pull tensile test is the preferred method. However, complications arise where laboratories are equipped with compression testing machines as opposed to tension testing machines. To overcome the problem, this laboratory has developed a direct tensile apparatus that may be fitted into any compression press or compression press triaxial chamber of suitable internal diameter. The tensile apparatus is unique in that as an axial compressive load is applied to the apparatus. tension in the axial direction is transmitted to the contained rock specimen.

The design and operation of the new tensile apparatus is described in this report. The results of tensile strength tests conducted on pink granite using four different tensile test methods are also presented.

---

*Physical Scientist, Canadian Mine Technology Laboratory
Mining Research Laboratories, CANMET, Energy, Mines and Resources Canada, Ottawa, Canada

Keywords:

Brazilian test, triaxial extension test, direct tensile strength test.

ÉVALUATION PAR QUATRE DIFFÉRENTES MTHODES D'ESSAI DE LA RÉSISTANCE À LA TRACTION DU GRANITE DE TAILLE

par

B. Gorski*

RÉSUMÉ

De nombreux dispositifs ont été mis au point au cours des ans pour déterminer la résistance à la traction de la roche. Les dispositifs exploitent des méthodes tant directes qu'indirectes d'essai, puis de mesure de la résistance à la traction de la roche. La plus courante de ces méthode est l'essai de traction directe. Cependant, un problème se pose lorsqu'un laboratoire est équipé d'une machine d'essai de compression au lieu d'une machine d'essai de traction. Pour résoudre ce problème, le présent laboratoire a mis au point un appareil de traction directe qui peut être adapté à toute chambre à presse de comporession uniaxiale ou triaxiale de diamètre intérieur approprié. L'appareil de traction est unique du fait que lorsqu'un effort de compression axial est appliqué à l'appareil, la traction dans la direction axiale est transmise à l'éprouvette de roche à l'essai.

La construction et le fonctionnement du nouvel appareil sont décrits dans le présent rapport. Les résultats des essais de traction menés sur du granite rose au moyen de quatre méthodes d'essai de traction différentes sont aussi présentés.

---

*Chercheur en sciences physiques, Laboratoire canadien de technologie minière, Laboratoires de recherche minière, CANMET, Énergie, Mines et Ressources Canada, Ottawa, Canada

Mots clés:

essai brésilien, essai de traction triaxiale, essai de traction directe

TABLE OF CONTENTS

		Page
	ABSTRACT	i
	RÉSUMÉ	ii
1.0	INTRODUCTION	1
2.0	APPARATUS DESIGN	3
3.0	SPECIMEN PREPARATION	4
4.0	BRAZILIAN TEST	5
5.0	DOUBLE-CORED DIRECT TENSILE TEST	6
6.0	TRIAXIAL EXTENSION TEST	6
7.0	NEW DIRECT TENSILE TEST	8
8.0	TEST RESULTS	8
9.0	TENSILE STRENGTH	9
10.0	OBSERVATIONS	9
11.0	CONCLUSIONS	10
12.0	REFERENCES	11

FIGURES

No.			
Fig.	1	Detail of new direct tensile apparatus	2
Fig.	2	Specimen geometry	3
Fig.	3	Specimen grinding set-up	5
Fig.	4	Specimen geometry (by Luong)	6
Fig.	5	Triaxial extension test set-up	7

1. INTRODUCTION

The tensile strength of rock specimens has been investigated by many researchers in the field of rock mechanics using different test configurations. As rock is much weaker in tension than in compression, the need for reliable tensile tests requires special attention. Various methods for tensile strength of rocks, such as the direct methods with special collars, grips, fixtures, involving the use of different bonding media at the gripping ends of the sample have come into practice. A review of the existing methods, bending tests, ring tests, disc tests and other miscellaneous methods has been presented by Vutukuri et al. [1]. The validity of tensile strength values derived using these methods is dependent on a uniform stress distribution being applied during testing. Vutukuri has expressed doubt in the reliability of results derived using these indirect methods.

Of the known indirect methods, the Brazilian disc test is the most commonly used, due to the ease of sample preparation and set-up, but the direct-pull method is considered to be the best for any effective evaluation of the tensile strength of rock. However, the application of direct methods to rocks introduces difficulties in gripping the specimen without damaging the surface, in applying a tensile load that is parallel to the axis of the specimen to prevent bending of the sample and to avoid abnormal stress concentration at the grip ends. These difficulties are more apparent when short samples are to be tested in the laboratory.

This laboratory has developed a simple tensile apparatus to perform tensile strength tests on rock specimens (Fig. 1). The apparatus is unique in that it is designed to fit in a compression press having no tension capabilities. The compression of the apparatus in the press transmits direct tension in the rock specimen. The apparatus can be installed in a triaxial chamber, and by suitably jacketting the specimen, the specimen may be failed in tension in confined conditions.

A test program was undertaken to assess the validity of tensile strength test results determined on granite rock specimens using the new test apparatus. The test results were compared with Brazilian, triaxial extension and double-cored tensile tests. The test results are presented in this report including the design and operation of the tensile apparatus.

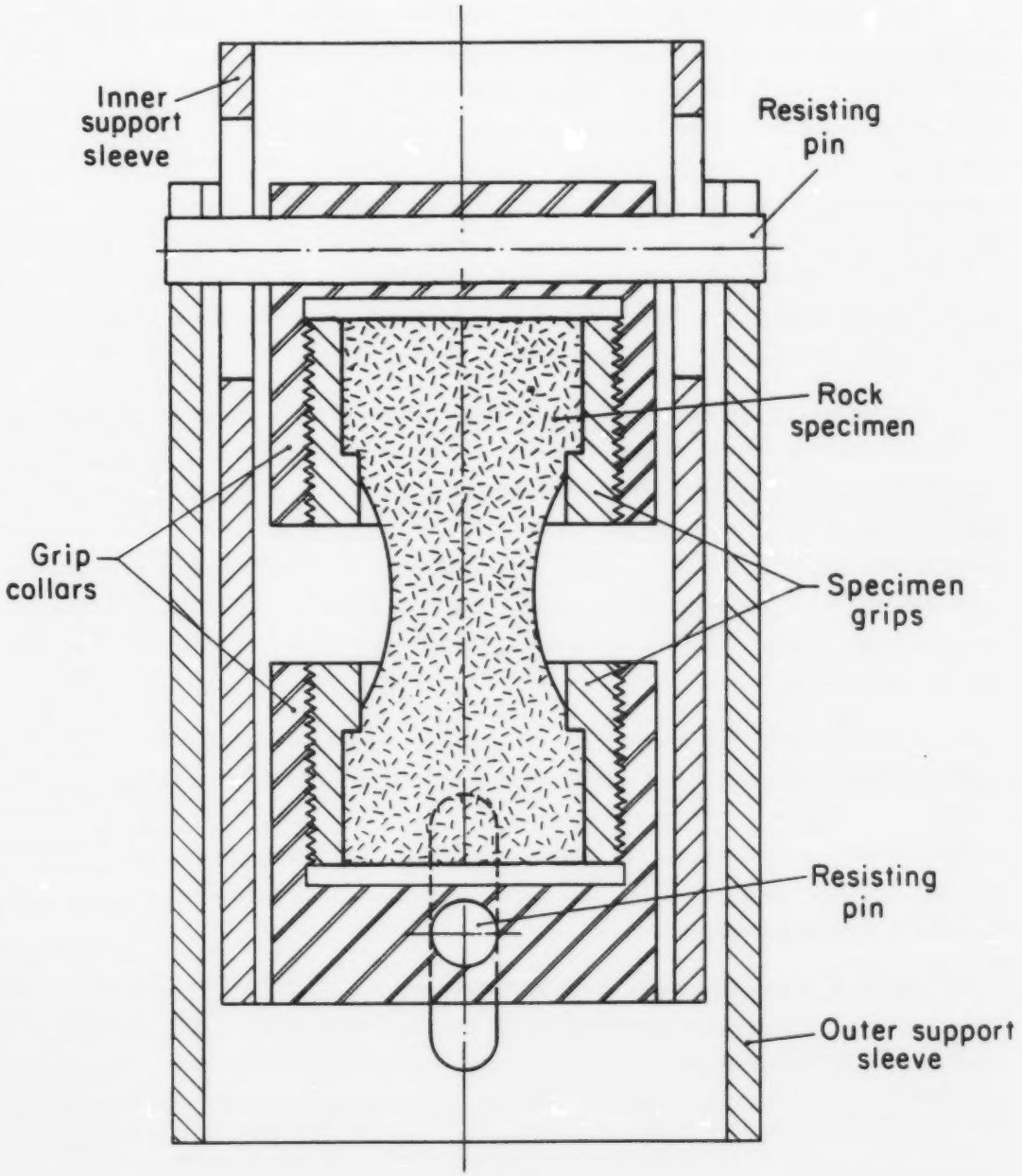

Fig. 1 Detail of new direct tensile apparatus

2. APPARATUS DESIGN

The test apparatus is suited to 45 mm diameter rock specimens having lengths of approximately 100 mm. However, the apparatus may be made to suite any required specimen size. Figure 1 illustrates the design details of the split grip tensile apparatus in cross section. All the machined parts are made of mild steel. In order to ensure perfection in the alignment of the specimen to the loading axis, the grips are split then machined and threaded as a single piece. The split grips hold the specimen near it's ends.

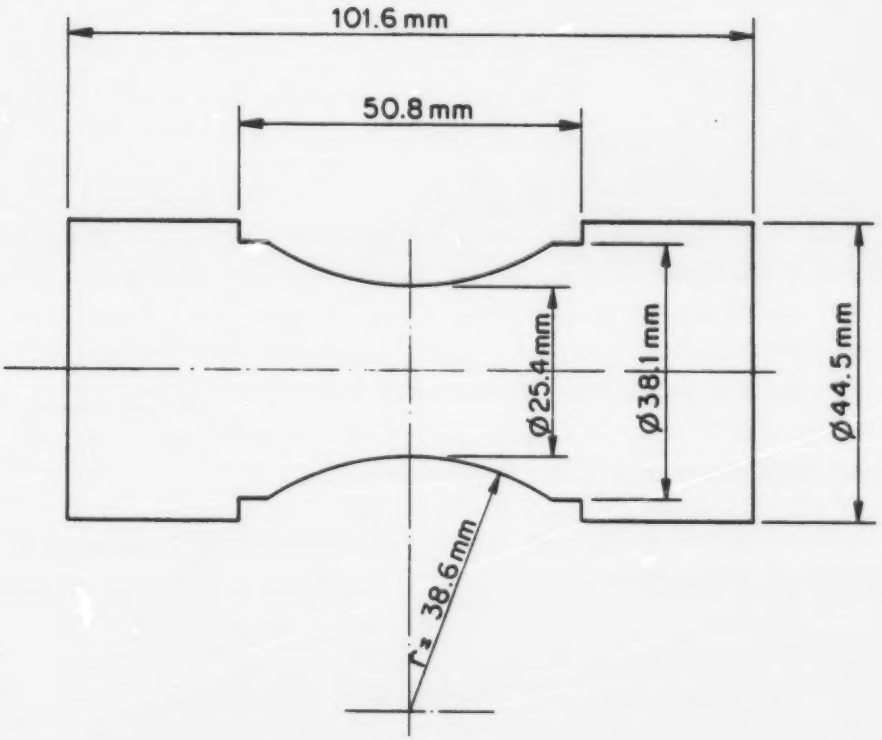

Fig. 2 Specimen geometry

The split grip sets are shouldered with internal diameters of 44.45 mm and 38.10 mm. This shoulder mates the shoulder of the rock specimen thereby allowing the rock to be pulled apart (Fig. 2).

The split grip pairs, once on the cylindrical ends of the rock specimen, are then threaded as a unit into the grip collars. Once the grip collars are threaded on, a cylindrical sleeve, having two holes at the top, is installed over the assembled rock specimen.

A hole through the bottom grip collar is aligned with two holes through the sleeve and a resisting steel pin is slid into place. A hole through the top grip collar is aligned 90° to the bottom grip collar hole. A resisting steel pin is then slid through the two slotted holes drilled through the upper part of the steel sleeve and through the top grip collar hole. The assembled sample together with the sleeve are then installed in a larger diameter sleeve and suspended on it by the upper pin bearing on two half slotted holes located at the top of the outer sleeve. The apparatus is self-aligning under load.

3. SPECIMEN PREPARATION

Test specimens were prepared from a block of pink granite originating from Cold Spring Quarry, Pinawa, Manitoba. Cylindrical specimens were cored from the test block using impregnated diamond thinwall core barrel. All specimens were cored in the same reference plane. The direct tensile specimens were end lapped prior to cylindrical contouring. Cylindrical contouring was accomplished used a machinist's lathe equipped with a tool post grinder (Fig. 3). The grinder was equipped with a diamond impregnated grinding wheel. The specimens were shouldered to accommodate the grip restraining seats (Fig. 2). The middle least diameter ensured failure at the mid-section.

Triaxial extension test specimens were prepared using the machinist's lathe. These specimens were prepared without shoulders.

Fig. 3 Specimen grinding set-up

Rock core specimens selected for direct tensile tests were prepared with lengths 102 mm. Brazilian tensile strength specimens were prepared with length to diameter ratios of 1:2. All specimens were lapped to within specified MRL tolerances, oven dried, weighed and dimensioned. Specimen preparation was performed according to the procedures used at MRL [2].

4. BRAZILIAN TEST

The test measures the uniaxial tensile strength of rock specimens indirectly. The test is based on the experimental fact that most rocks in biaxial stress fields fail in tension at their tensile strength when one principal stress is tensile and the other finite principal stress is compressive with a magnitude not exceeding three times that of the tensile principal stress. The test specimens were loaded to failure at diametrically opposed surfaces using a 2000 kN ELE compression press. The test procedure conformed to ISRM standards [3].

5. DOUBLE-CORED DIRECT TENSILE TEST

Two specimens were tested in direct tension using an ELE compression press. The test method was developed by Luong [4] and specimen geometry is shown in Figure 4.

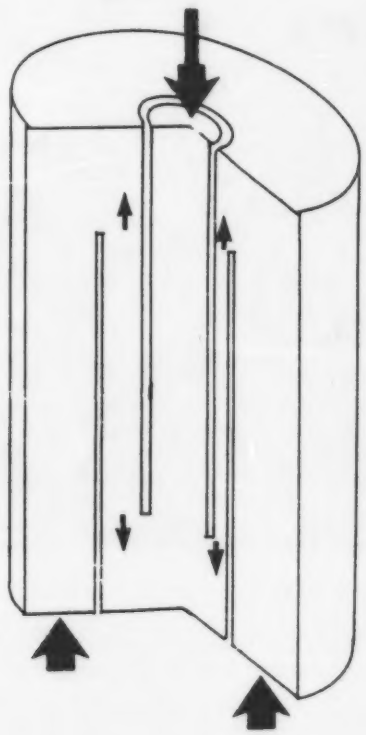

Fig. 4 Specimen geometry (by Luong)

6. TRIAXIAL EXTENSION TEST

Two specimens were tested using a 'BX' Hoek cell and an MTS compression press. The test method was developed by Brace [5]. Figure 5 shows the test set up. Modelling clay was used as the medium to transmit side pressure from the straight sided urethane jacket to the curved surfaces of the specimen.

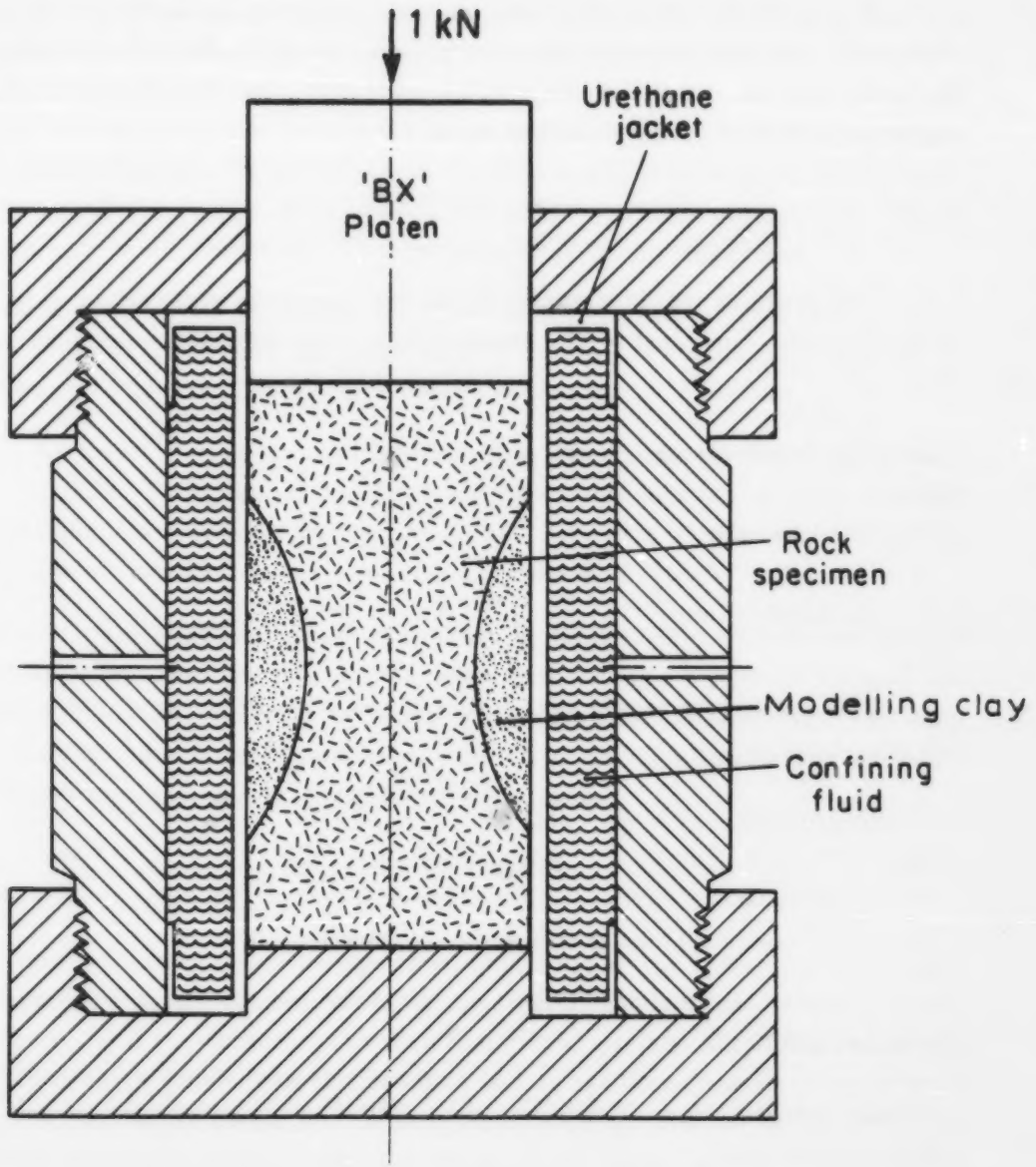

Fig. 5 Triaxial extension test set-up

7. NEW DIRECT TENSILE TEST

Five specimens were tested using the new apparatus and an ELE 2000 kN compression press. The specimen was loaded in pressure control until specimen failure occured. Specimen load was monitored using a pressure transducer. The stress rate applied to the specimen conformed ISRM prescribed standards.

8. TEST RESULTS

The Brazilian tensile strengths of the test specimens were calculated using the following formula. These test results originate from a test program undertaken by Wiseman [6].

Brazilian tensile strength $\sigma_t = \frac{2P}{\pi D t}$ (MPa)

where

P = Load at failure (N)

D = Diameter (mm)

t = Thickness (mm)

The double core tensile strengths of the test specimens were calculated using the following formula.

Tensile strength $\sigma_t = \frac{P}{A_o}$ (MPa)

where

P = Load at failure (N)

A_o = Cross-sectional area at failure zone (mm^2)

The triaxial extension tensile strengths of the test specimens were calculated using the following formula.

Tensile strength $\sigma_t = \frac{\sigma_3(A_1 - A_2)}{A_2} - \frac{P}{A_2}$ (MPa)

where

A_1 = Cross-sectional area at sample end (mm^2)

A_2 = Cross-sectional area at failure zone (mm^2)

σ_3 = Confining pressure at failure (MPa)

P = Axial preload (N)

9. TENSILE STRENGTH

The tensile strength, σ_t, obtained by the Brazilian test was 9.48±0.53 MPa. Brazilian test specimens were 25.5 mm in diameter, approximately the same diameter. The throat diameter of the new direct tensile and triaxial test specimens were 25 mm in diameter. The Brazilian tensile strength as determined by Annor and Jackson [7] for the same pink granite was 9.32±1.26 Mpa. Their results were based on test specimens 45 mm in diameter. The closeness of the two values confirms the reproducibility of this test method. Tensile strength/size scale effects between the two specimen sizes was not significant.

The pink granite tensile strength determined by the test method proposed by Luong was 5.46±0.07 MPa. The tested specimens were 63 mm in outside diameter and had an internal diameter of 32 mm. The specimen area in tension was 23.13 cm^2.

The pink granite tensile strength determined by the triaxial extension test method was 5.69±0.31 MPa. The specimen cross-sectional area at the location of failure was 5.07 cm^2. This failure area is considerably less than the failure area of specimens used in the Luong test method. However, both test results compared well.

The pink granite tensile strength determined by the new direct tensile test method was 4.87±1.45 MPa. The tensile strength values from Luong's test series method and the triaxial extension test series are within the range of tensile strength upper and lower deviation values of the new direct tensile test series. The Brazilian tensile strength values were 40% higher than the new direct tensile strength results.

10. OBSERVATIONS

The tests performed using the new direct tensile apparatus yielded tensile strength values comparable with the other methods used, excluding the Brazilian values. The test geometry lended itself to minimizing radial and tangential stresses. The direct tensile test yielded lower strength values than the Brazilian test as the direct tensile test is affected to a greater degree by the presence of microfractures and microfissures in the rock. The rock fails according to the 'weakest link'. For the specimens tested in direct tension, failure occured on a plane at the mid-section and perpendicular to the axis of the core according to theory.

The Brazilian test specimens failed vertically in a line through the points of load application according to theory. The higher value of tensile strength for the Brazilian test series was confirmed with two other rock suites. Grey granite from Pinawa, Manitoba had

a Brazilian tensile strength of 7.56 MPa and a direct tensile strength of 4.47 MPa. Diabase from Lac St. Jean, P.Q. had a Brazilian tensile strength of 16.33 MPa and a direct tensile strength of 10.39 MPa. For the pink granite, grey granite and diabase, the Brazilian tensile strengths were 40%, 41% and 36% greater respectively, than the direct tensile strengths.

11. CONCLUSIONS

The pink granite tensile strength was determined using the new direct tensile apparatus. The tensile strength was found to be 4.87±1.45 MPa. Brazilian tensile strengths were found to be 40% higher. The higher result may be attributed to the combination of compressive and tensile stresses imposed on the rock using this test method. The compressive force must overcome the frictional forces at shearing grains or grain boundaries in order to initiate tensile failure.

Tensile strengths determined using Luong's method and the triaxial extension test method confirm the tensile strength result obtained using the new direct tensile test apparatus to be acceptable. The new direct tensile apparatus offers an inexpensive alternative method for conducting tensile tests on rock specimens. The apparatus is configured such that any compression press may be used to apply load to the tensile apparatus. The apparatus is also designed to fit into a triaxial chamber, thereby allowing the specimen to be laterally confined.

12. REFERENCES

1. Vutukuri, V.S., Lama, R.D. and Saluja, S.S. "Handbook on mechanical properties of rocks"; *Trans Tech Publications, U.S.A.*; 1974.

2. Gyenge, M. and Herget, G. "Pit slope Manual 3-2; Laboratory tests for design parameters"; *Report* 77-26; CANMET, Energy, Mines and Resources Canada; 1977.

3. Brown, E.T. "Rock characterization testing and monitoring"; *ISRM*; *Pergamon Press, London, England*; 211p; 1981.

4. Luong, M.P. "Direct tensile and shear strengths of Fontainebleau sandstone"; *CNRS UA* 317; Solid Mechanics Laboratory, Ecole Polytechnique, Palaiseau, France; 1988.

5. Brace, W.F. "Brittle fracture of rocks";*Memorandum RM*-3583; Int. Conf. on State of Stress in the Earth's Crust-Preprints of Papers; pp2-5 to 2-103; May, 1963.

6. Wiseman, T. "Size/tensile strength relationships of Pinawa pink granite tested by the Brazilian method"; *Report* 91 – 021; CANMET, Energy, Mines and Resources Canada; 1991.

7. Katsube, T.J. and Hume, J.P. "Geotechnical studies at Whiteshell research area (RA-3)"; *Division Report MRL* 87-52(*INT*); CANMET, Energy, Mines and Resources Canada; 1987.